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Carbon Supply for Forest and Range Lands of California

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Summary of findings:

Afforestation of grazing lands provides the most carbon and at the least cost

Activity	Quantity of C—MMT CO_2			Area available—M acres		
	20 yr	40 yr	80 yr	20 yr	40 yr	80 yr
Forest management						
Lengthen rotation						
<$13.6	**2.2-3.5**	--	--	0.31	--	--
Increase riparian buffer-width						
<$13.6	**3.91** (permanent)				0.044	
Grazing lands						
Afforestation						
<$13.6	**887**	3,256	5,639	12.03	17.79	20.76
<$2.7	33	1,610	4,569	0.20	5.68	13.34

General approach for carbon supply

- Divide lands into three main categories:
  - Rangelands
  - Forests
  - Agriculture
- Identify options for enhancing carbon sequestration for each category
- Estimate:
  - Area available—how much and where
    - Spatial modeling and FIA data base
  - Amount of carbon sequestration over 20, 40, and 80 year periods
  - Costs (opportunity costs, conversion costs, maintenance costs, and measuring costs)

Rangelands

Photo: Union Lumber Company Collection (from Andrews 1965).

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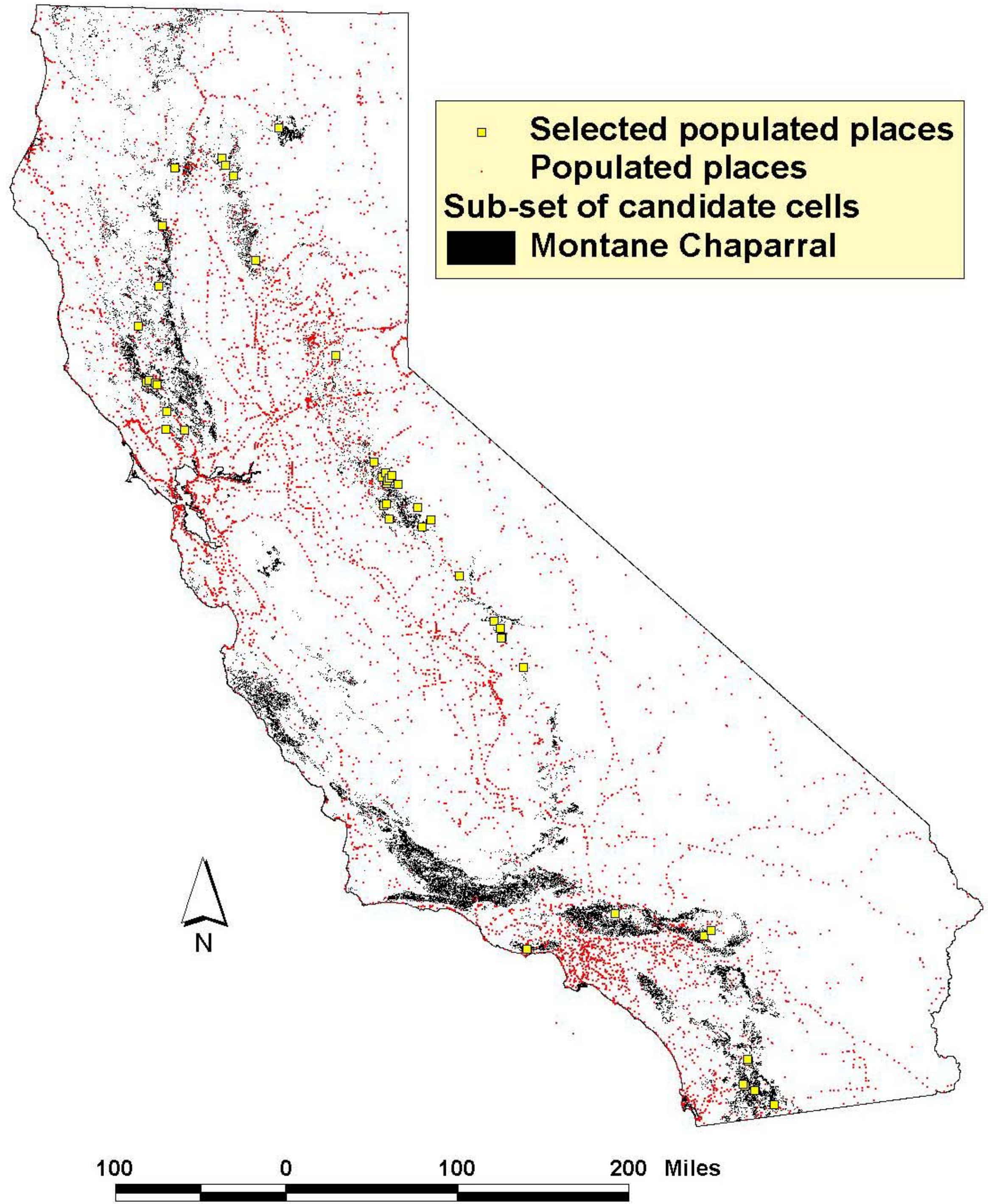
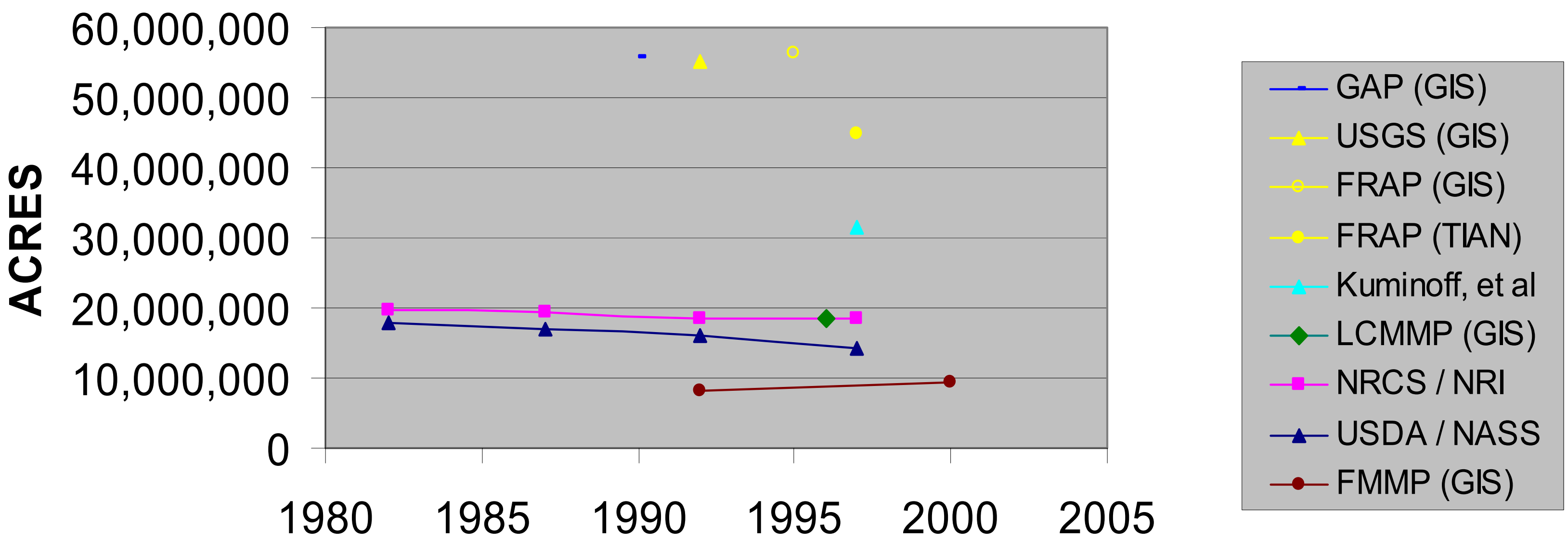


Map of populated places, montane chaparral areas, and selected populated places with names that refer to forests or forestry—e.g. Pine Grove, Pine Valley, Pinehurst, Redwoods, Sequoia, Seven Oaks, Sherwood Forest, Stallion Oaks, Sugarpine, Tall Timber Camp

Convert rangelands to forests

- Determine which rangelands could support forests—suitability analysis
  - Land-use suitability analysis based on
    - I. Biophysical factor-dependent suitability for forest habitats
    - II. STATSGO production map-based models to map suitability for forage and biomass production
- Analysis of rates of carbon accumulation
- Economic analysis

Areas of rangelands vary by source



Source	Data used	lands included
GAP (GIS)	UCal-SB's GAP analysis veg map reclassified using Melvin George's criteria for rangelands	all California
USGS (GIS)	National Land Cover Data (NLCD) aggregation of herbaceous and shrub classes	all California lands
FRAP (GIS)	CDF-FRAP multisource veg map reclassified using Melvin George's criteria for rangelands	all California
FRAP (TIAN)	statistics taken from Tian-Ting Shih's "Land Base of CA's forests" (1998)	all California
Kuminoff, *et al* *(AIC)*	aggregation of USDA/NASS, FMMP, FS and BLM data	all California lands
LCMMP (GIS)	LCMMP vegetation maps aggregation of herbaceous and shrub classes	for 5 LCMMP study areas
NRCS/NRI	sample points	private lands only -mostly rural
USDA/NASS	mailed census from farmers	private and BLM leased lands- agricultural counties predominate
FMMP (GIS)	FMMP maps of California agricultural areas	limited coverage of California's prime farmland counties

Suitability analysis for rangelands

Identify rangelands suitable for conversion to forests

- Analyze the relationship between existing forests and several biophysical factors using GEOMOD ="suitability for forest map"
- Cross-reference suitability map to areas of current rangelands to select areas with afforestation potential.

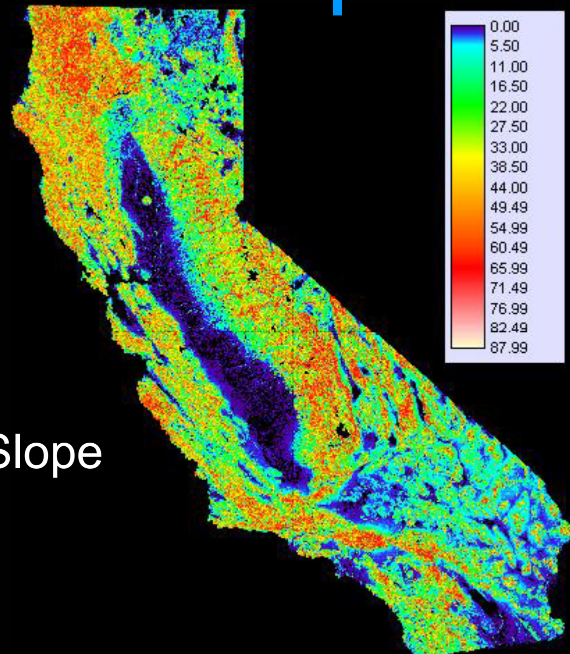
  Product = map of rangeland areas suitable to support forests
- Carbon sequestration in forest biomass derived from FIA and literature

  Product = map of carbon accumulation for afforesting rangelands

Prepare factor maps

Inputs to GEOMOD

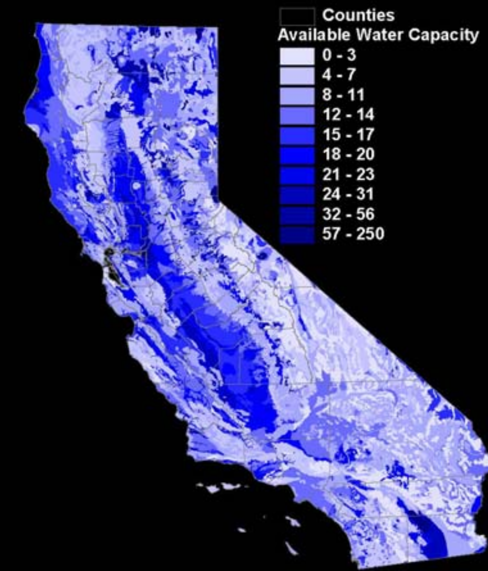
Converted to forest probability maps based on existing extent in each class



Slope

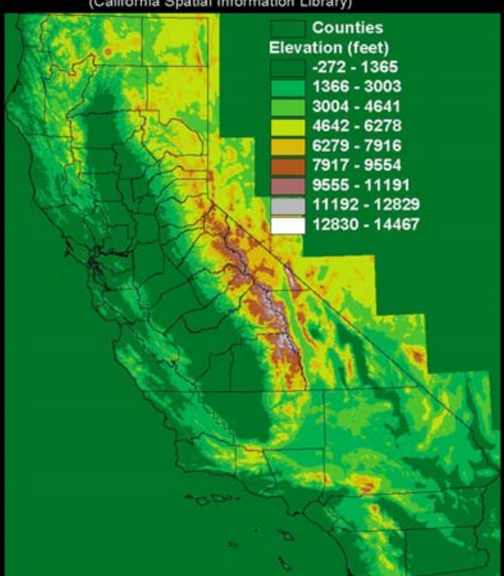
Available Water Capacity

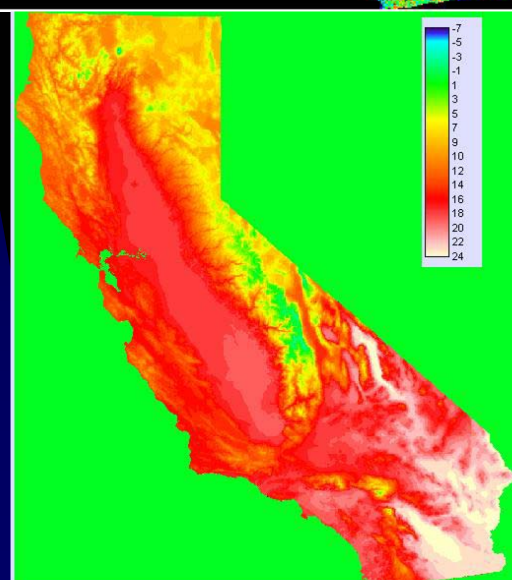
(STATSGO interpretation by Miller, D.A. and R.A. White, 1998)



Elevation

(California Spatial Information Library)

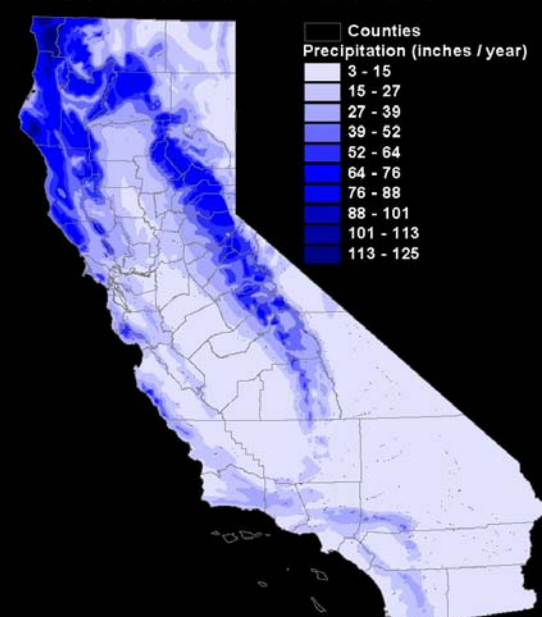




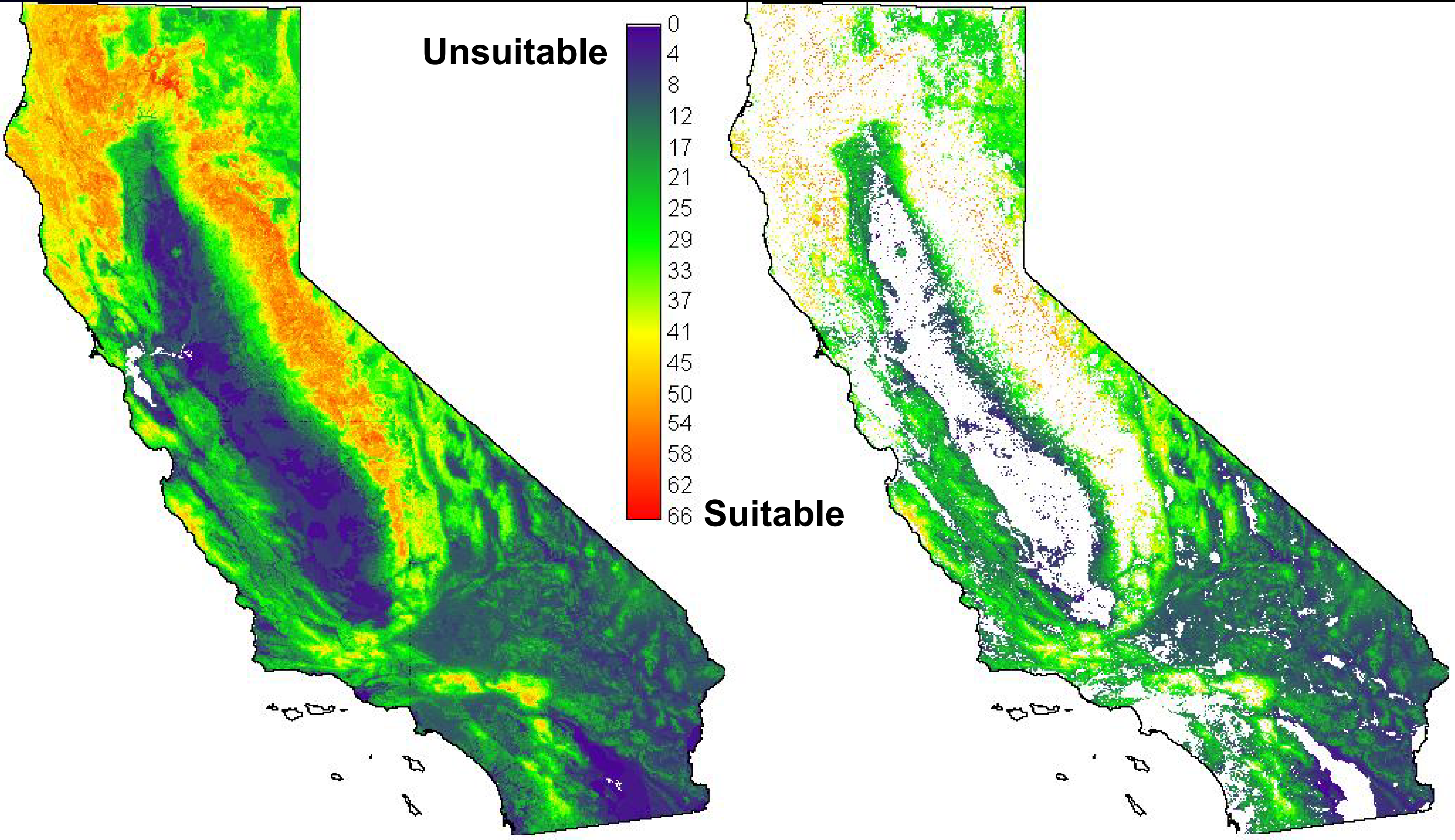
Mean annual temperature

Mean annual precipitation

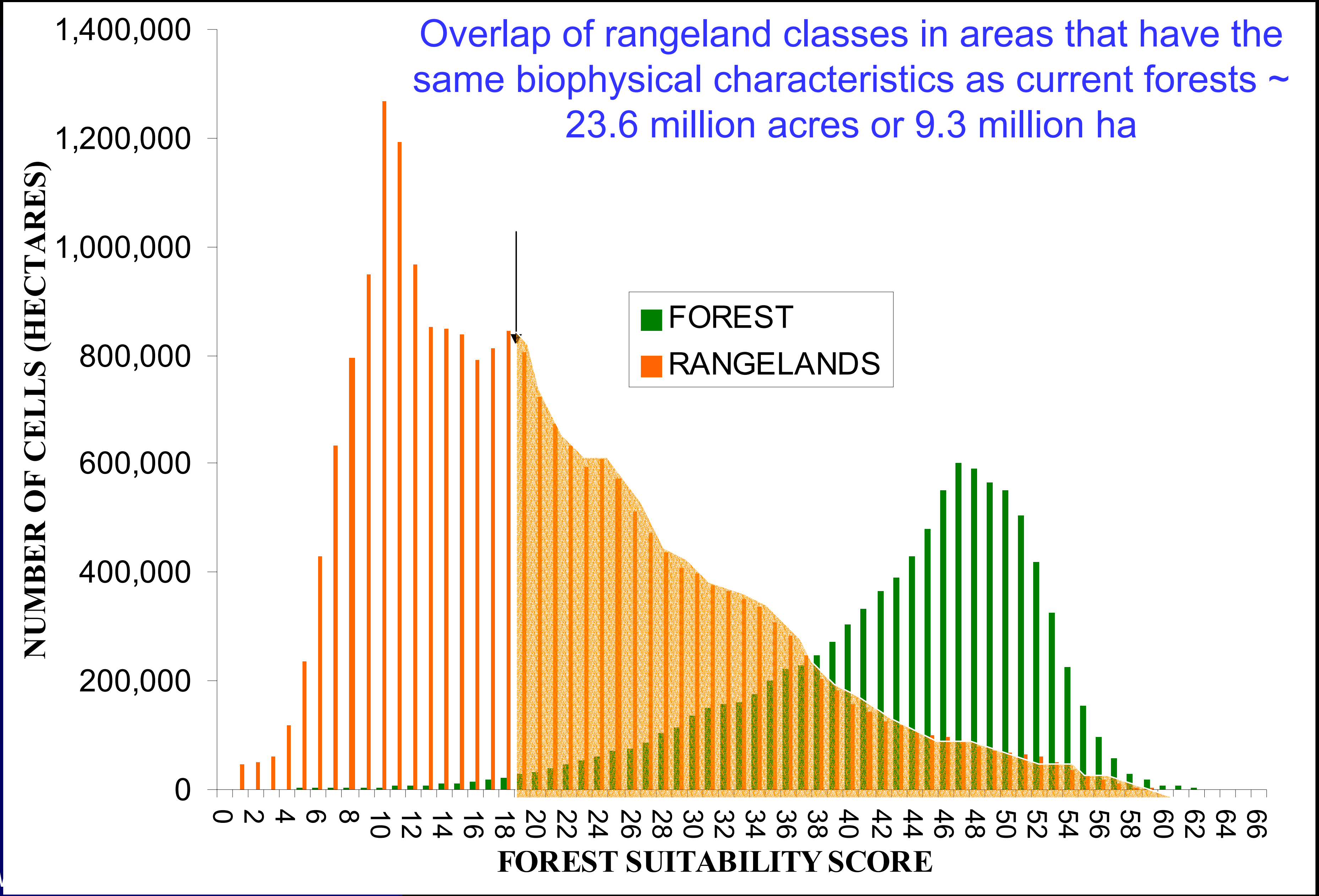
(California Spatial Information Library / USGS)



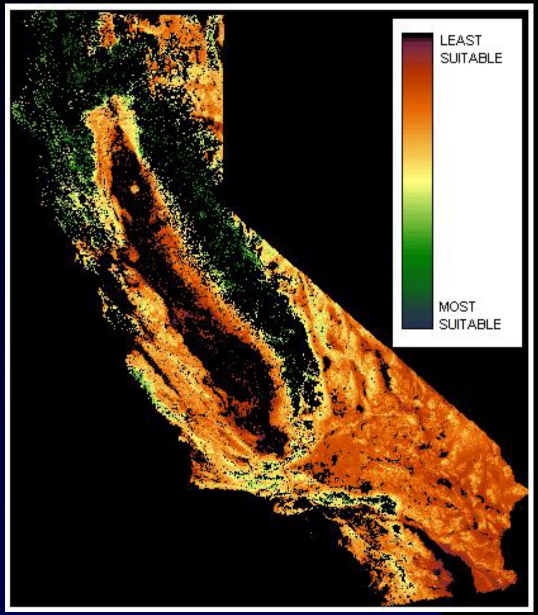
All areas suitable for forest growth (left) and rangeland areas suitable for forest growth (right)



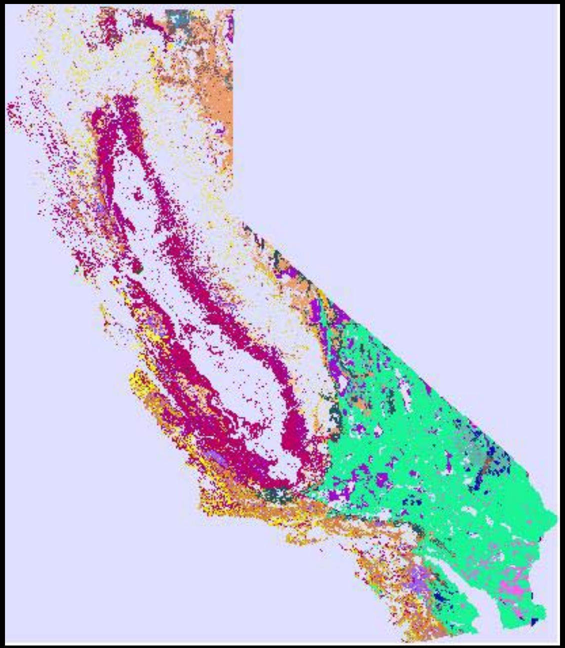
Area of existing rangelands suitable for forest growth



Suitable lands for forest

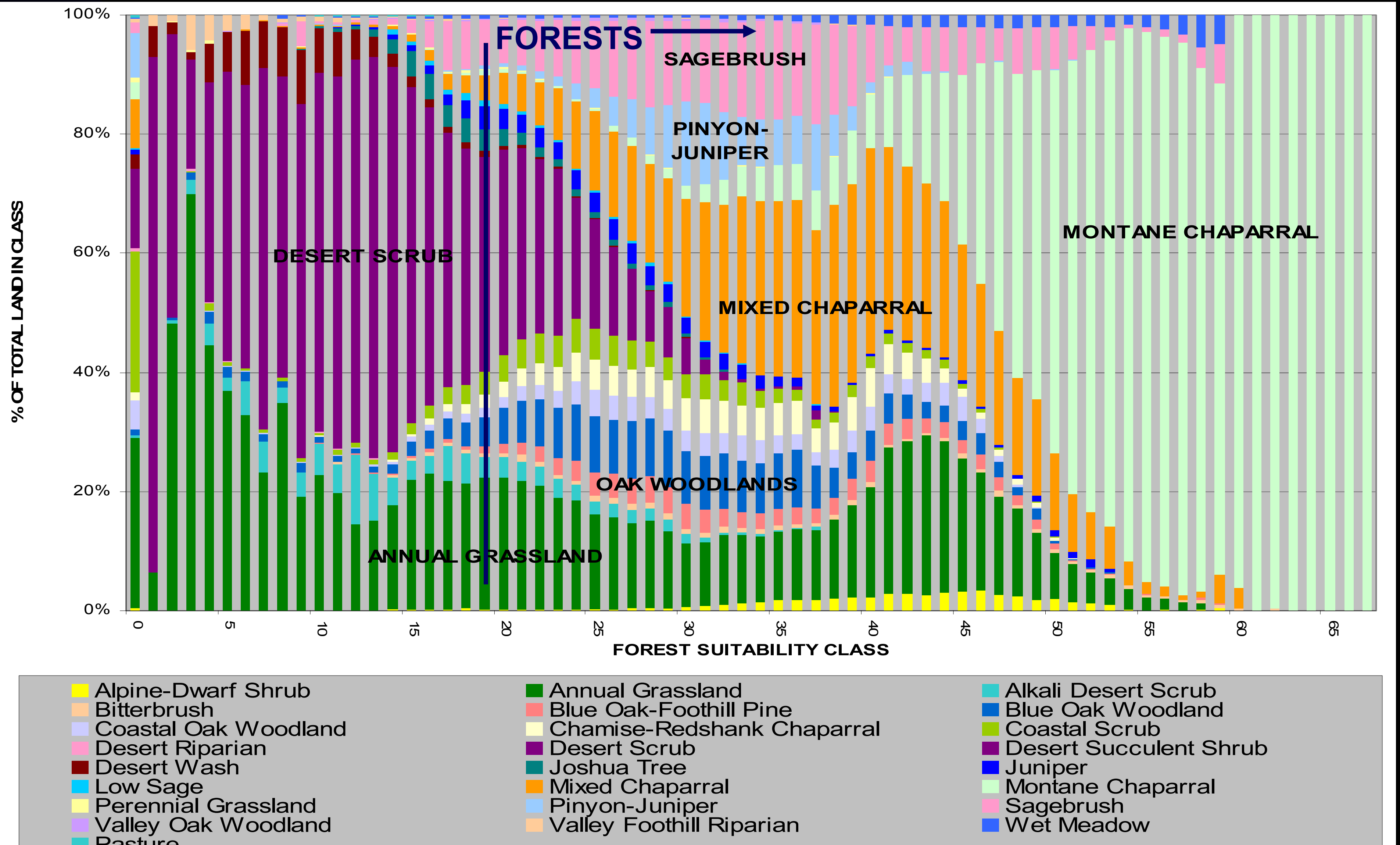


Current Rangeland types

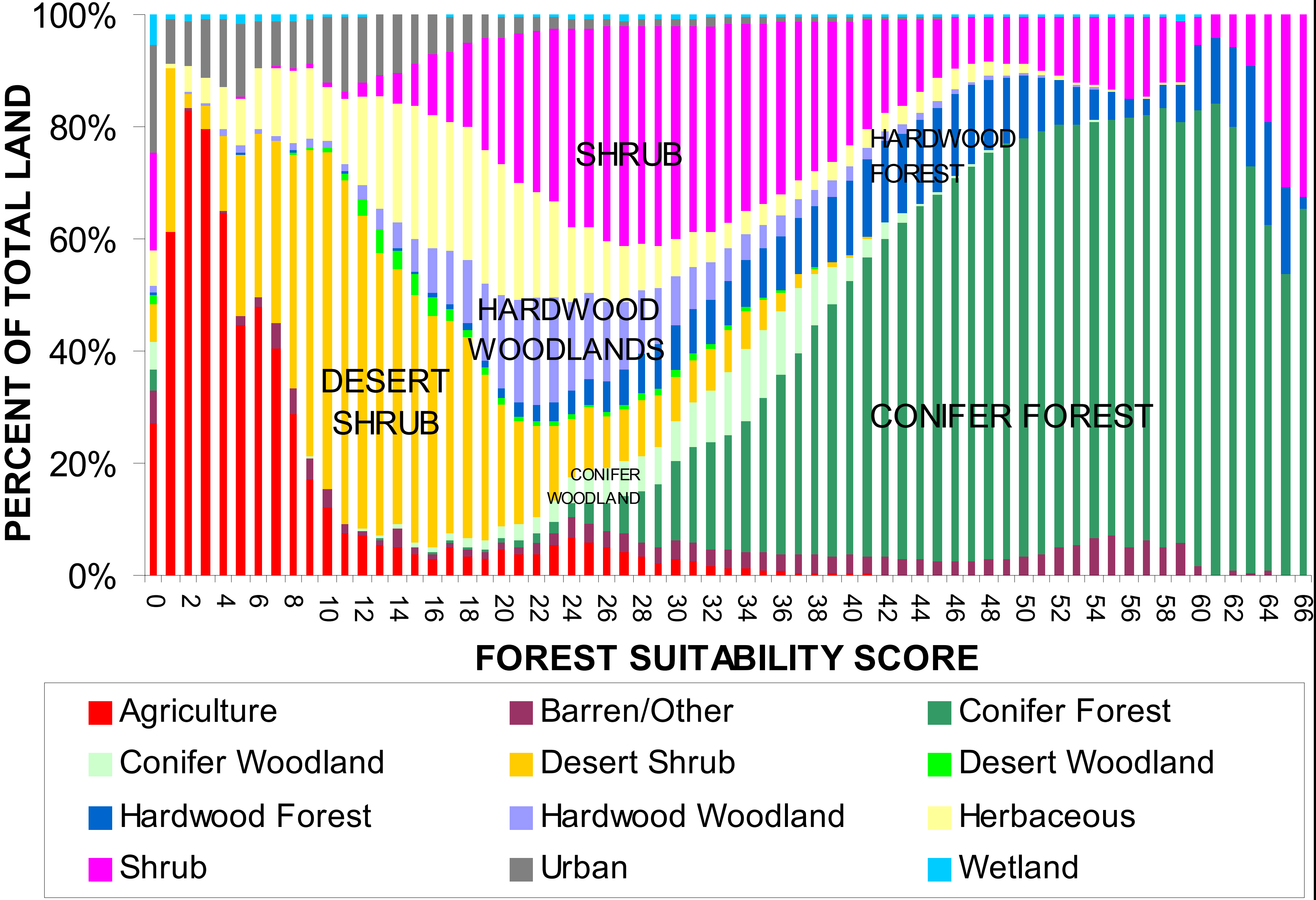


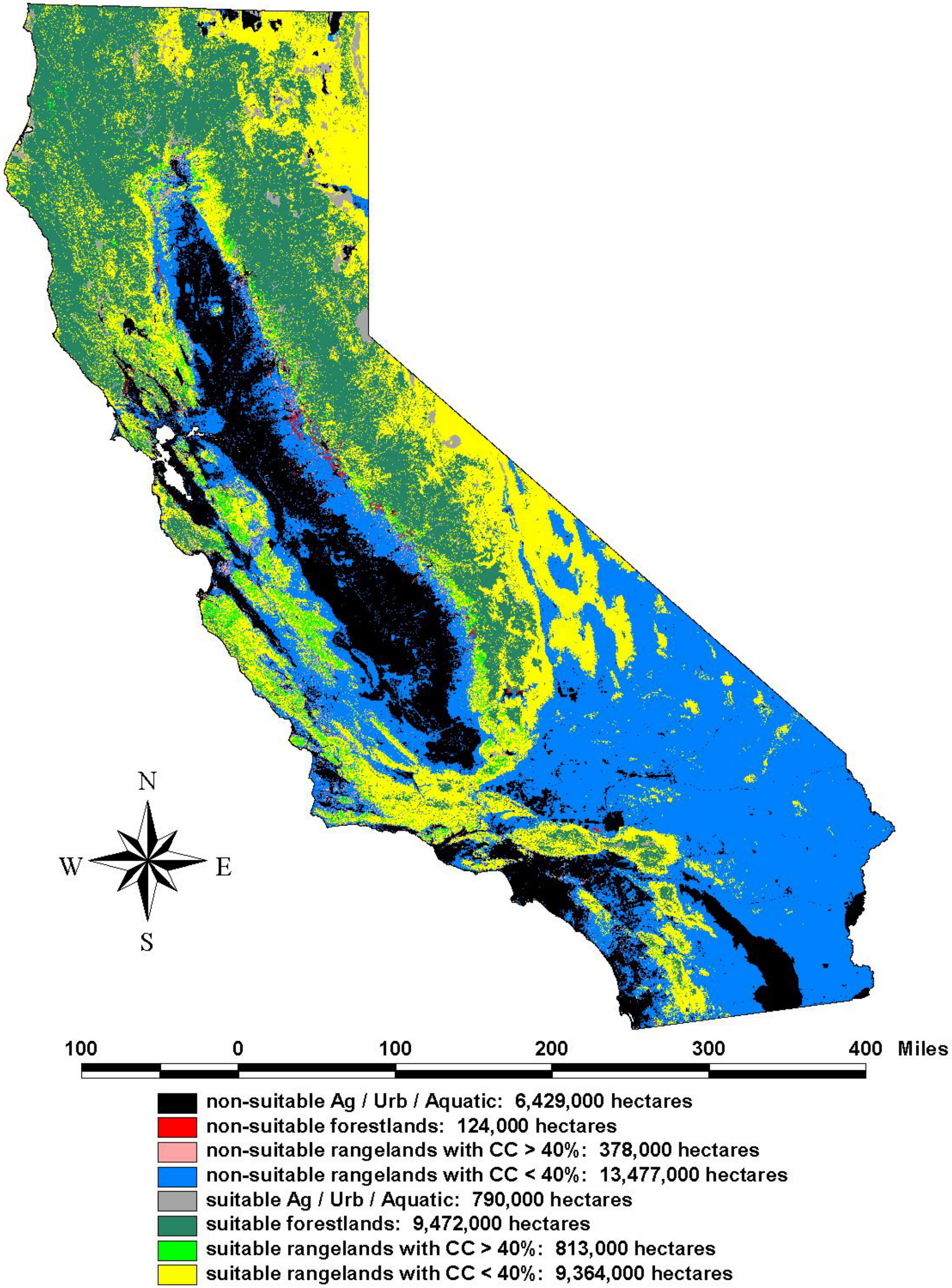
Which rangeland types show highest potential for forest?

Rangeland types suitable for forest growth



What type of forests are suitable?

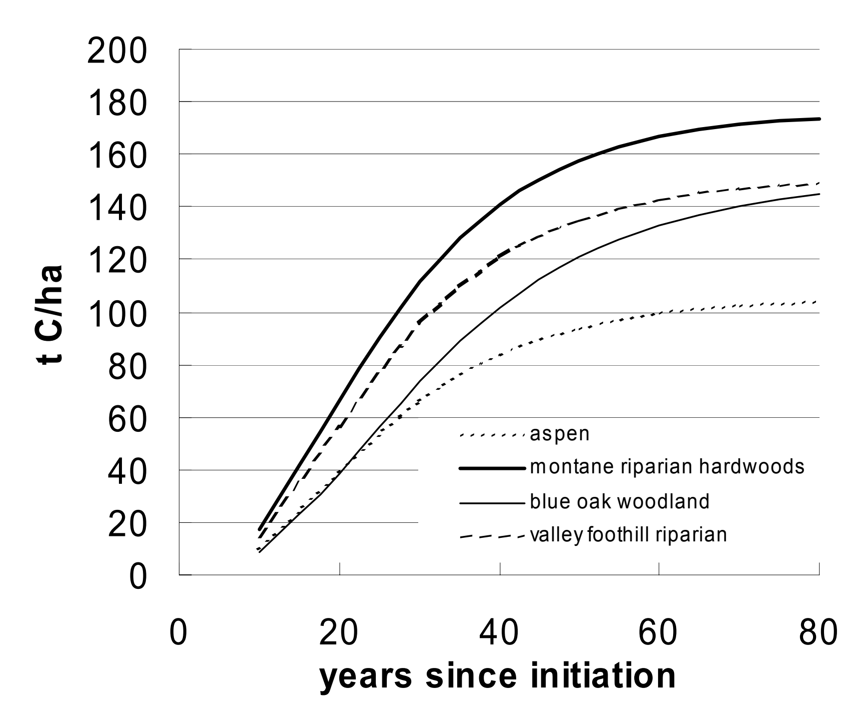




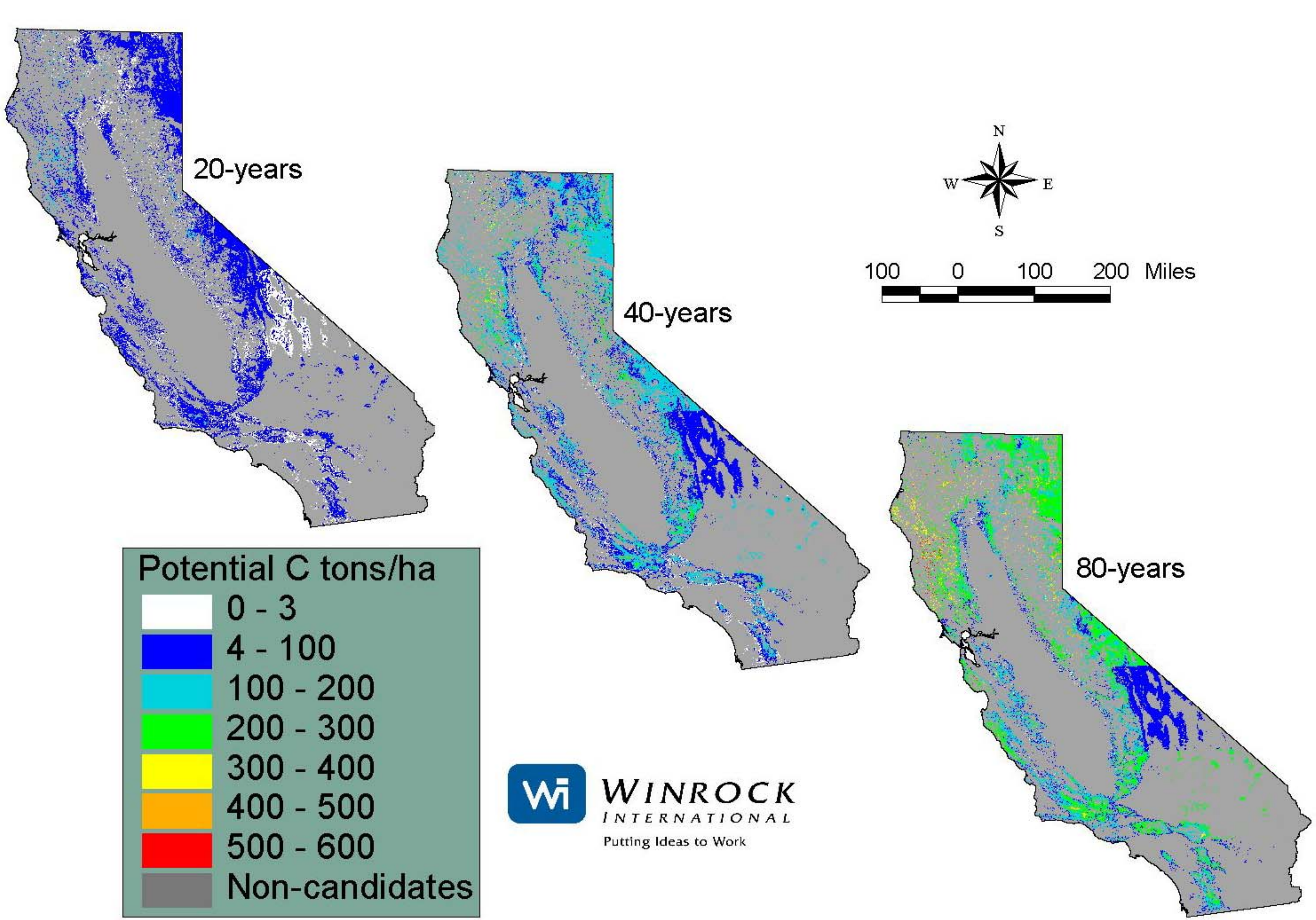
Map of rangeland areas (in yellow) suitable for afforestation

- *Represent about 24 million ac or 23% of State area*

Potential biomass-carbon accumulation in conifer and hardwood forests



Net carbon accumulation applied to potential woody-species distributions over three time periods

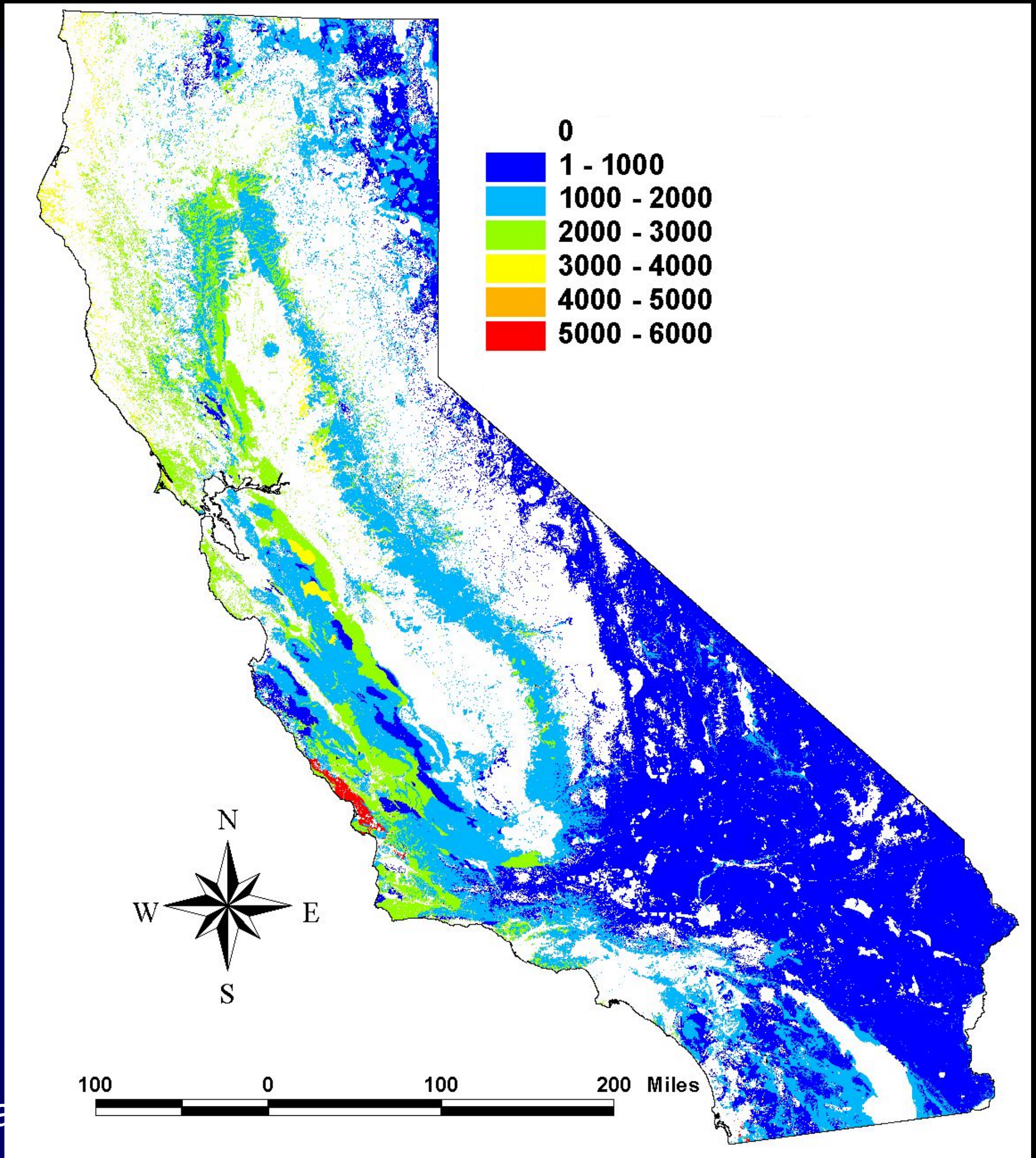


Cost of carbon sequestration

- Opportunity costs:
  - Using the same biophysical factors, a multivariate model was used to extrapolate STATSGO forage productivity data samples to a state-wide coverage.

    Product = map forage production
  - Economic analysis of forage value derived from national databases and field interviews
    - Mean annual profit/cow
    - Number of cows supported based strongly on forage production (1 animal unit month for CA = 791 lbs)

Estimated forage productivity across rangeland classes (lbs per acre per year)

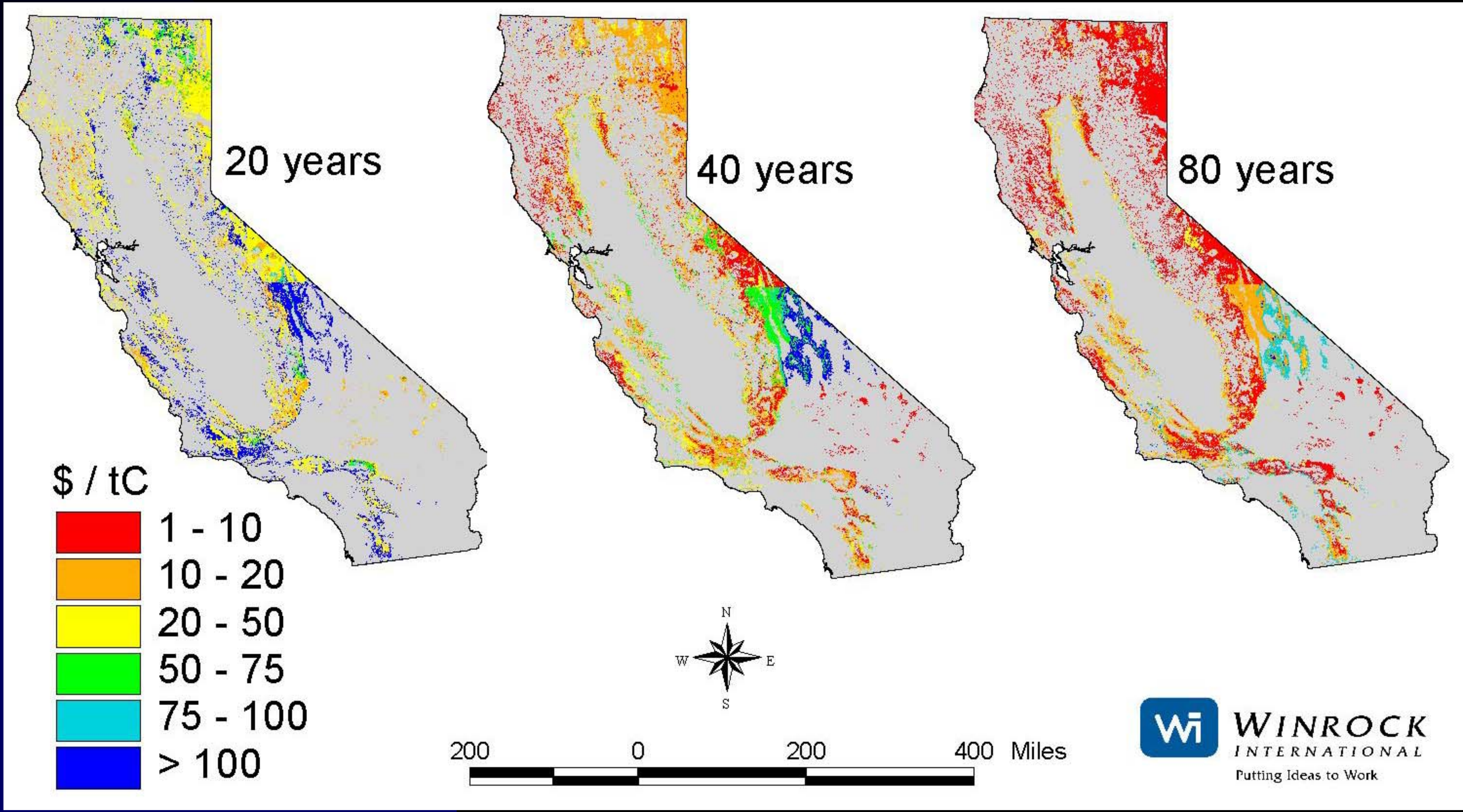


This map used to estimate number of cows per acre based on AUM and opportunity cost based on profitability per cow

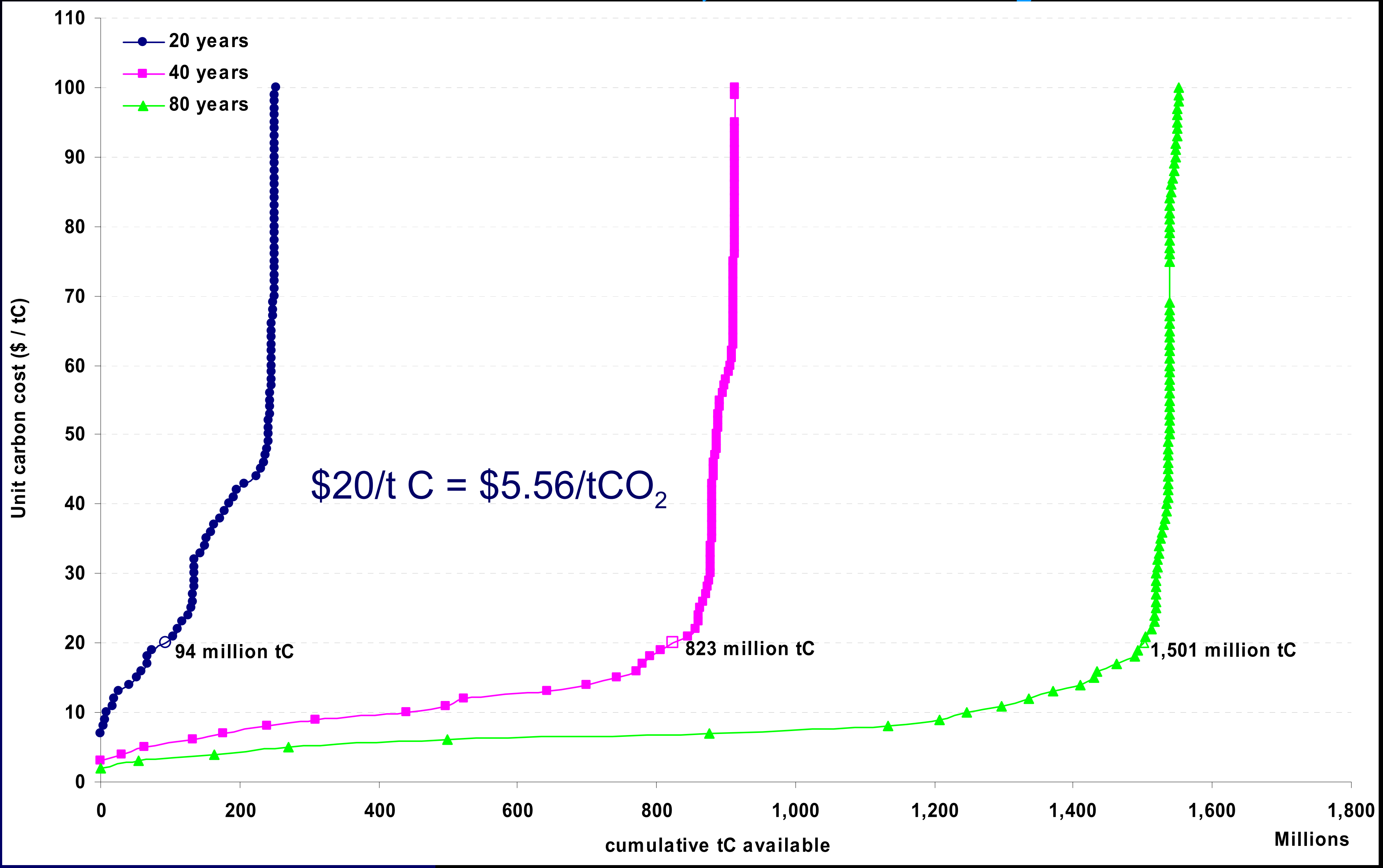
Cost of carbon sequestration

- Total cost, as net present value over life of duration of activity = opportunity cost + conversion cost + measuring&monitoring cost + maintenance cost,
  - Conversion costs—one time cost for planting trees (about $450/ha)
  - Measuring and monitoring costs over life of activity (about $2.5/ha annually)
  - Maintenance costs—replanting, fencing, chemical additions (about $20/ha annually for 5 years)

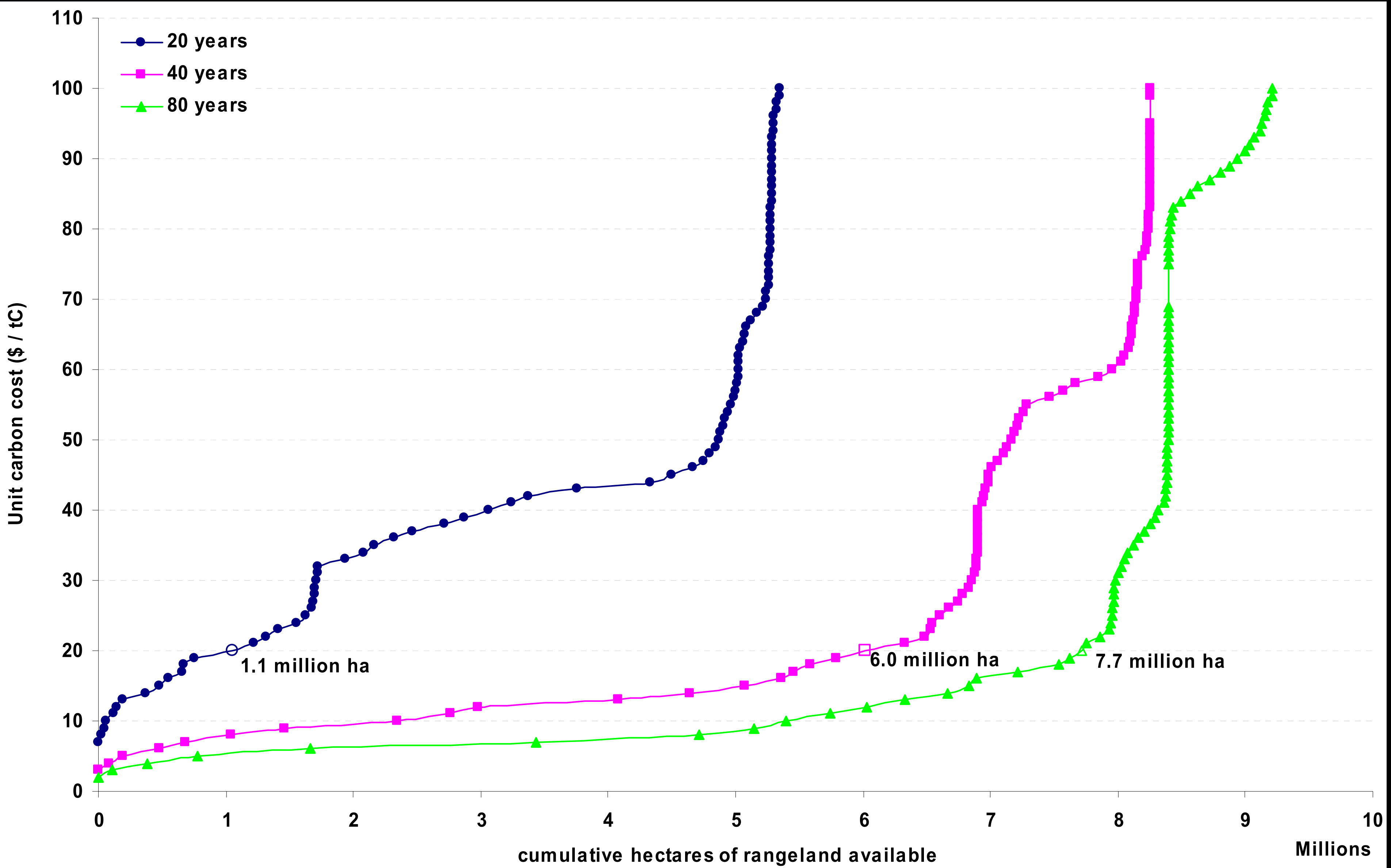
Cost of carbon sequestration through afforestation of California rangelands



Carbon supply curves for afforestation activities for 20, 40 and 80 years

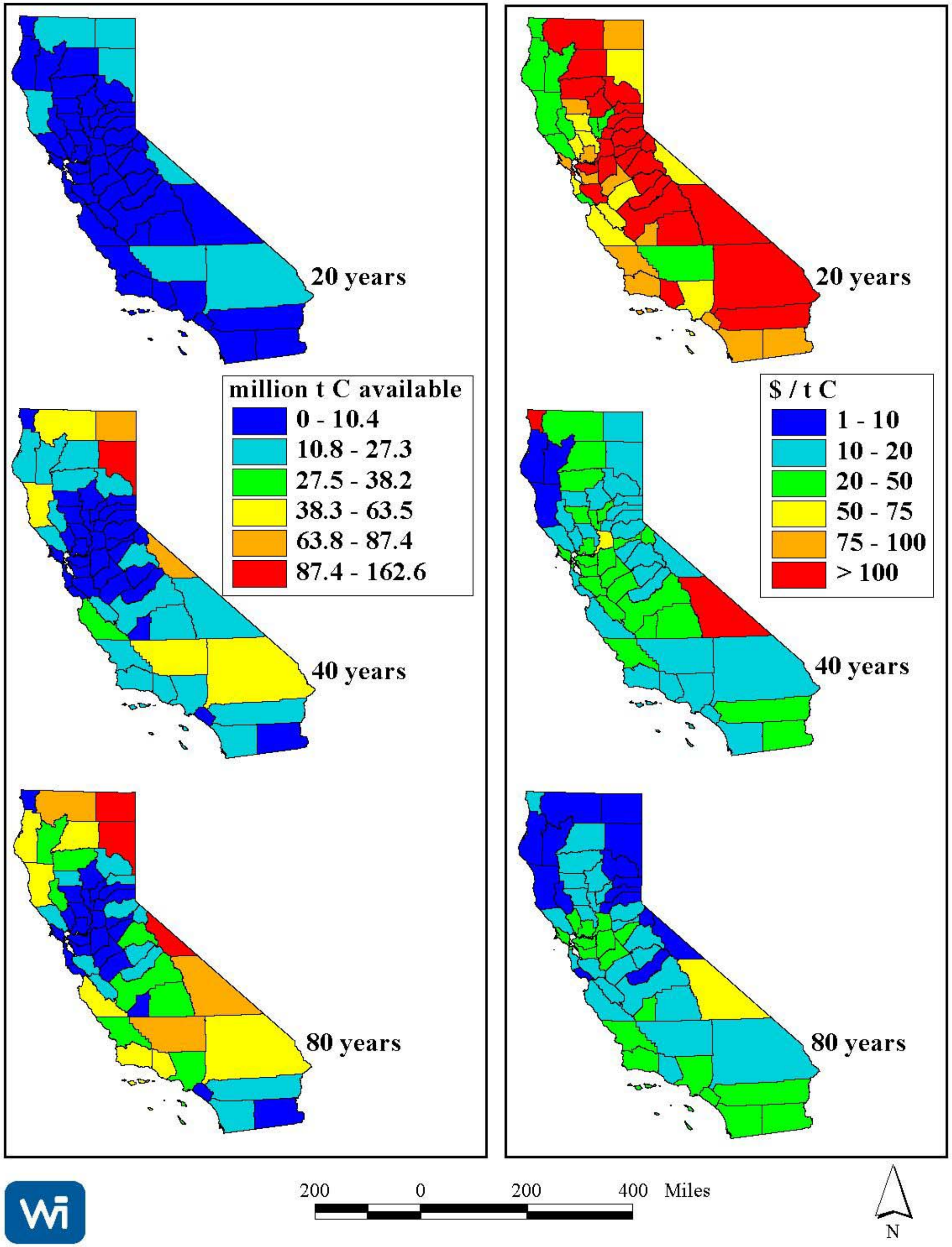


Area of rangelands for afforestation activities at different price points



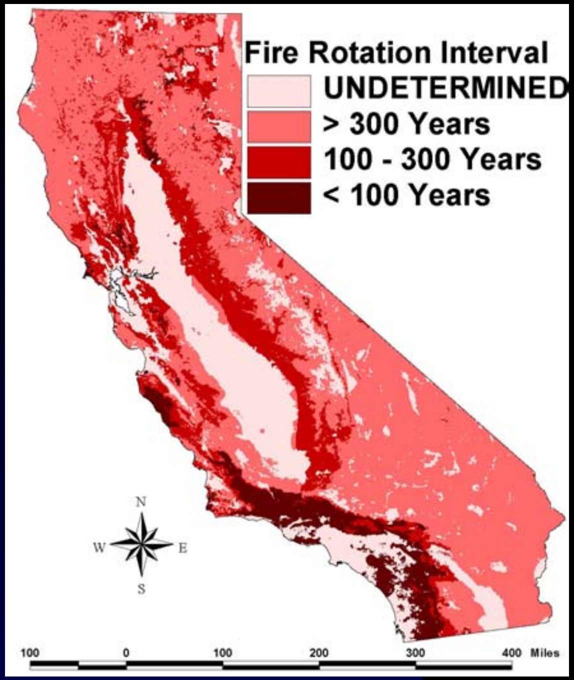
Quantity of CO_2 and area of rangeland for cost of up to \$5.5/t CO_2(\$20/t C)

Life of Activity	Carbon Supplied (million tons CO_2)	Rangeland (million ac)	Percentage of Suitable Rangeland
20	338	2.72	14%
40	3,018	14.8	68%
80	5,504	19.0	83%



Total carbon sequestered by afforestation of rangelands and area-weighted average cost $/t C and after 20, 40 and 80 years

To convert to $/ metric t CO2, divide by 3.6



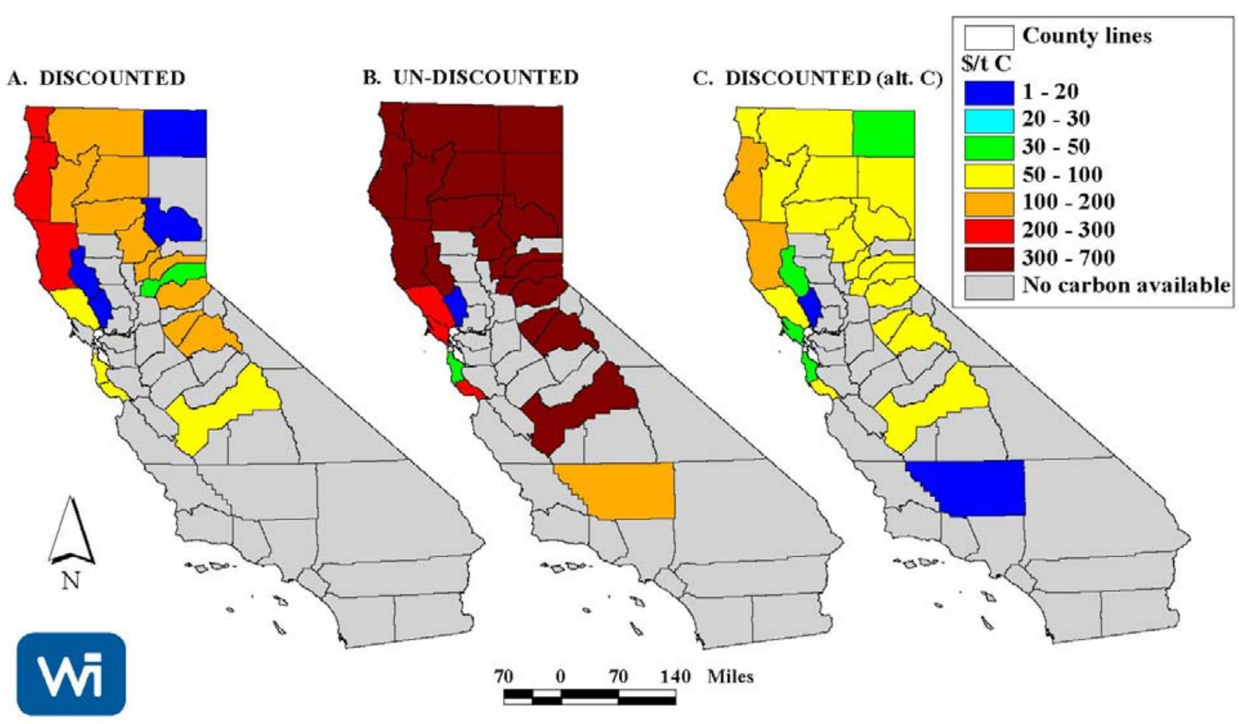
Percentage of afforestable rangelands at various levels of fire risk

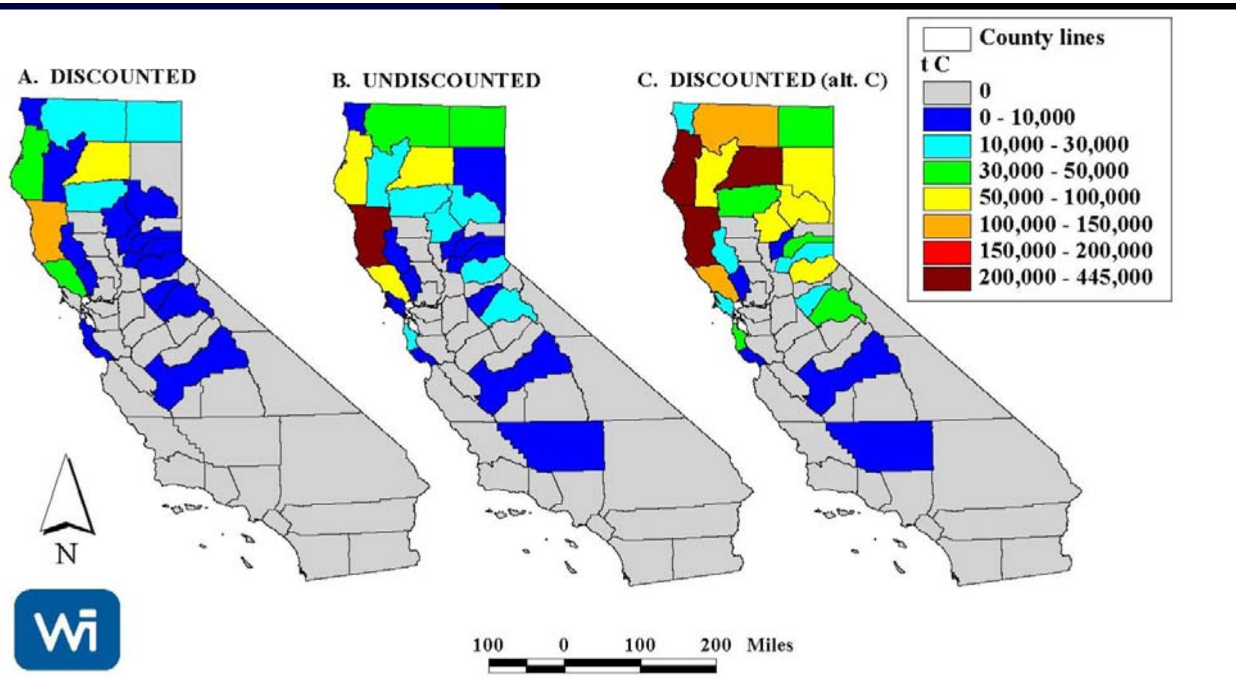
Fire rotation interval	% of area	20-year	40-year	80-year
UNDETERMINED	8%	$107.53	$28.14	$14.32
MODERATE	49%	$120.01	$59.53	$20.25
HIGH	29%	$111.65	$23.16	$15.24
VERY HIGH	15%	$122.07	$15.97	$22.91

Forests

Four alternatives analyzed:

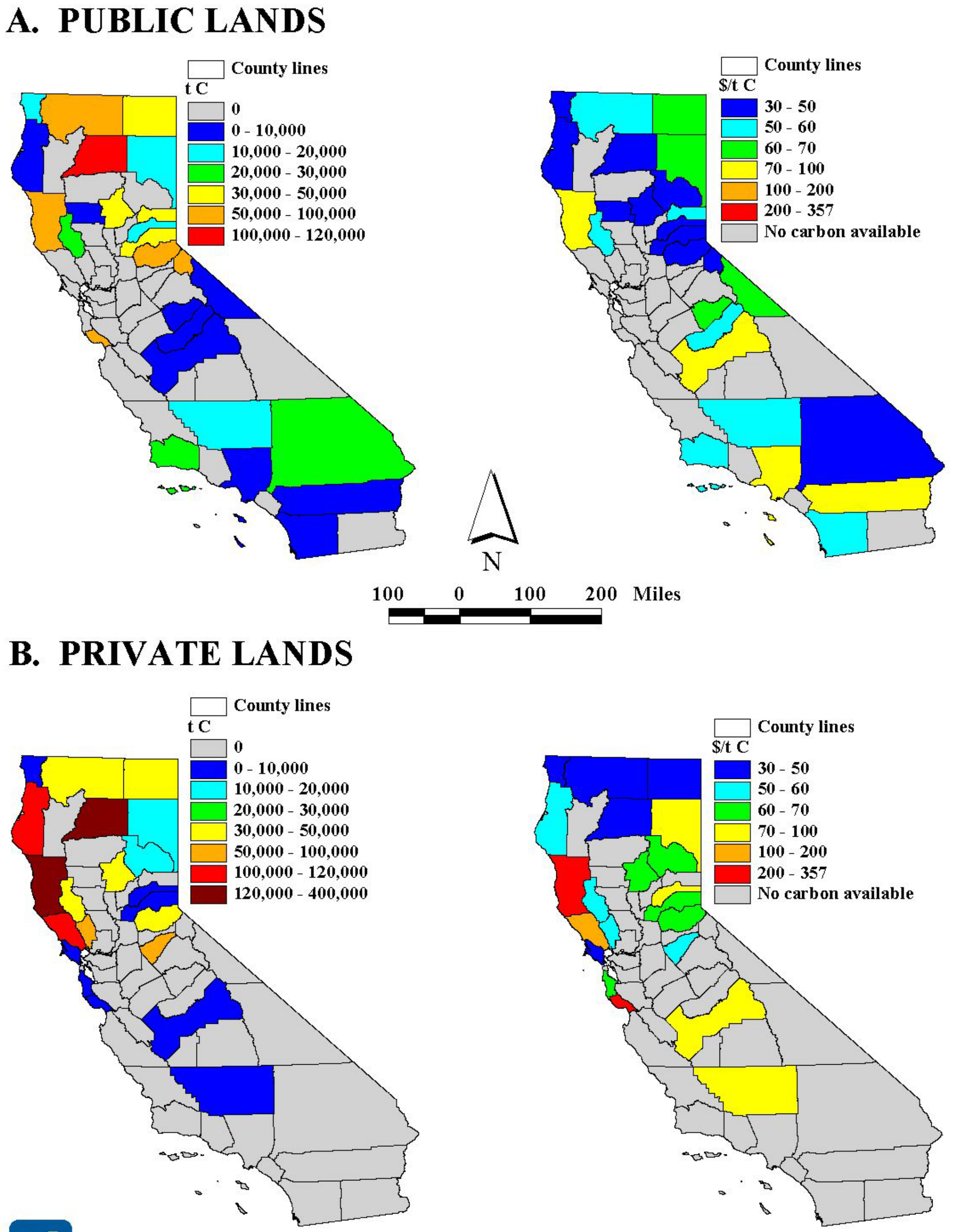
- Estimates were derived for 20 year and/or permanent contract periods:
  - ✓ (1) allowing timber to age, i.e. lengthening rotation time;
  - ✓ (2) increasing the riparian buffer zone by an additional 200 feet;
  - (3) changing traditional clear cuts to group selection cuts—*little to no increase in carbon sequestration;*
  - ➢ (4) forest fuel reduction to reduce hazard of catastrophic fires, and subsequent use of biomass in power plants





Alternative 1: County level costs and quantities of carbon for lengthening the forest rotation time by 5 years

The two methods of discounting carbon (A. and C.) are related to how the emissions from the initial harvest are counted.

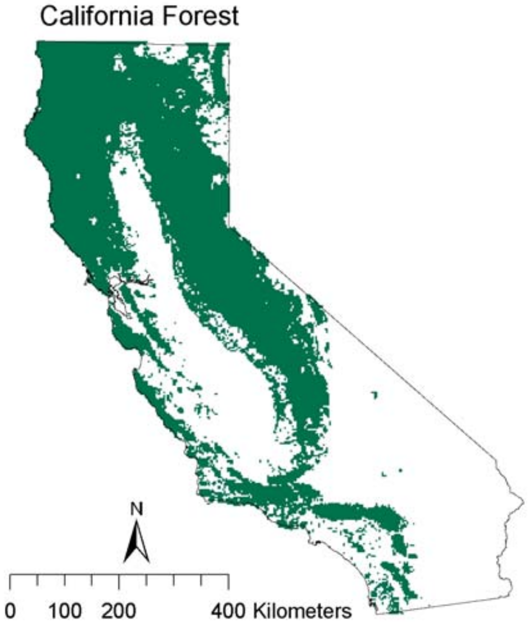


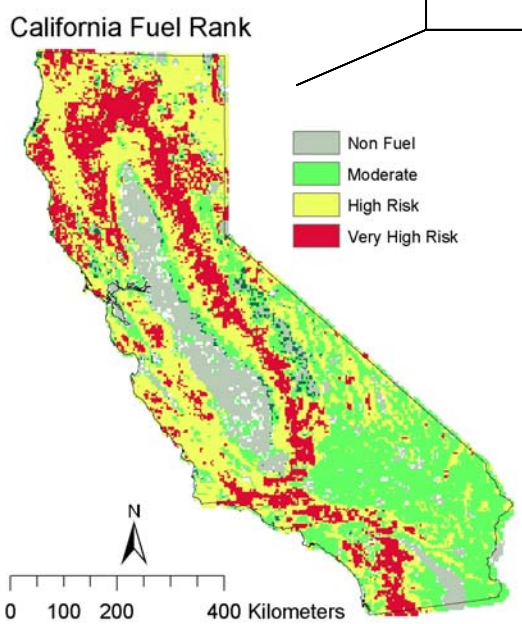
Alternative 2: County level quantity of carbon and cost by extending riparian buffers 100 feet on both sides of perennial streams on public and private lands.

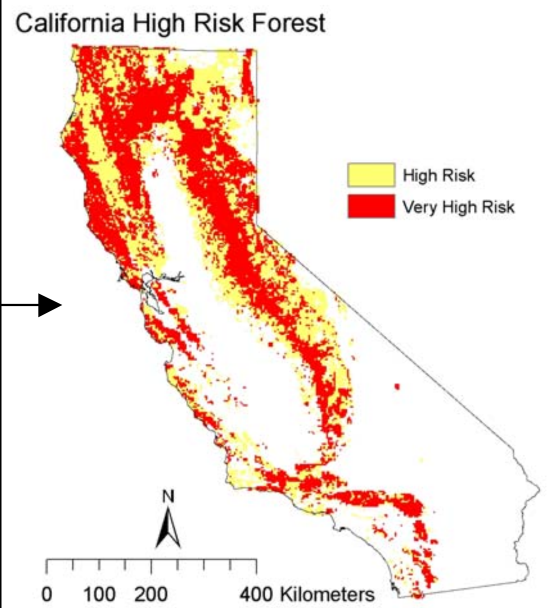
Alternative 3: forest fuel reduction

- Estimate the areas and carbon stocks of forests suitable for fuel reduction to reduce their fire risk and their location relative to existing power plants
- Develops a “Suitability for Potential Fuel Reduction (SPFR)” score for high fire risk forests based on slope, distance to biomass plants, and distance from roads
- SPFR scores rank areas feasible for transporting the removed fuels to biomass power generating plants

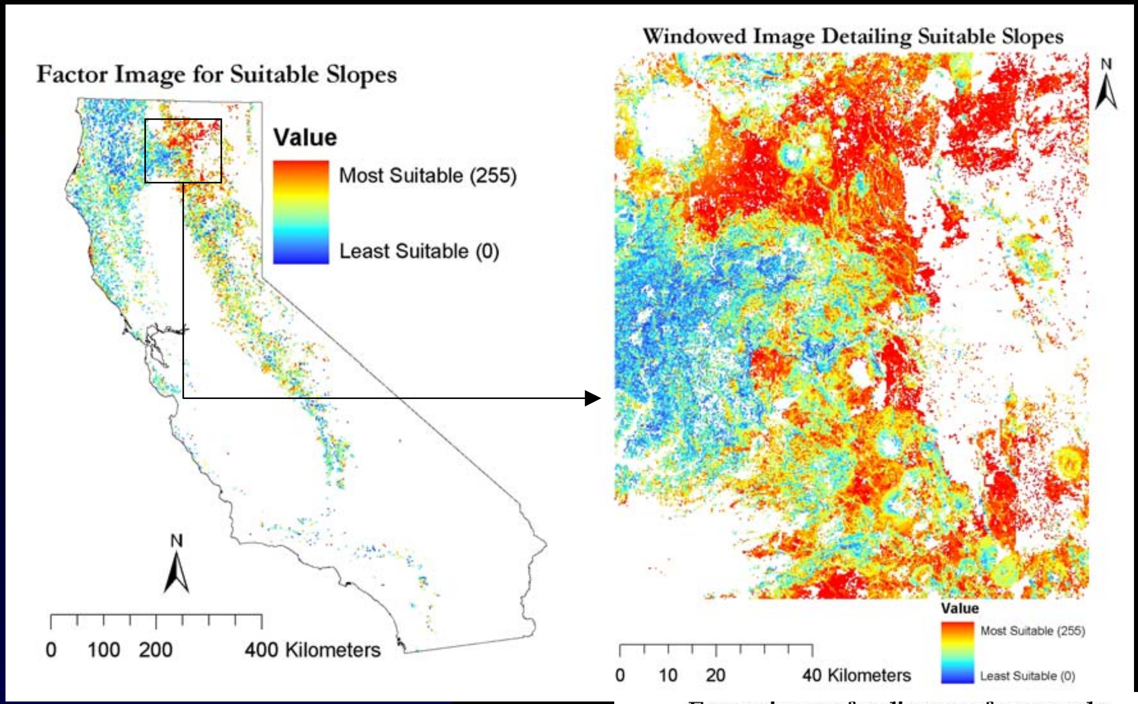
Distribution of California's forests at high and very high risk for catastrophic fire

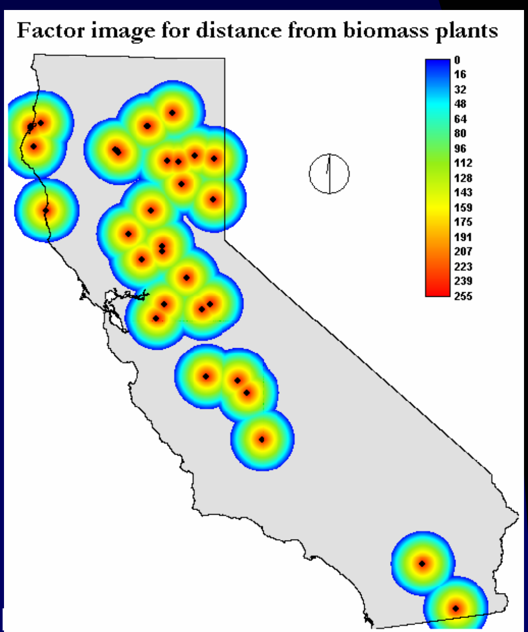


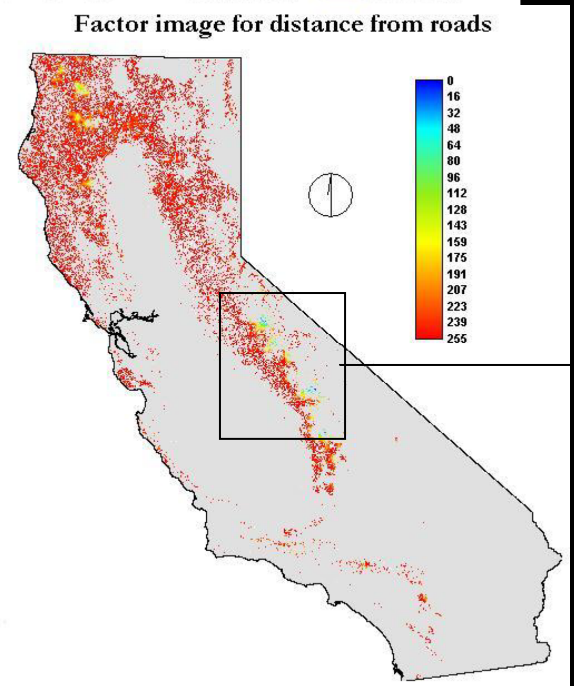


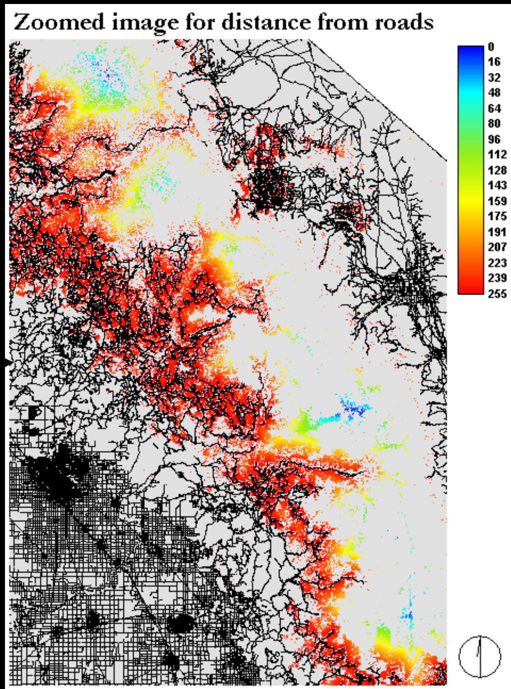


Factors used to develop index of suitability for fuel reduction



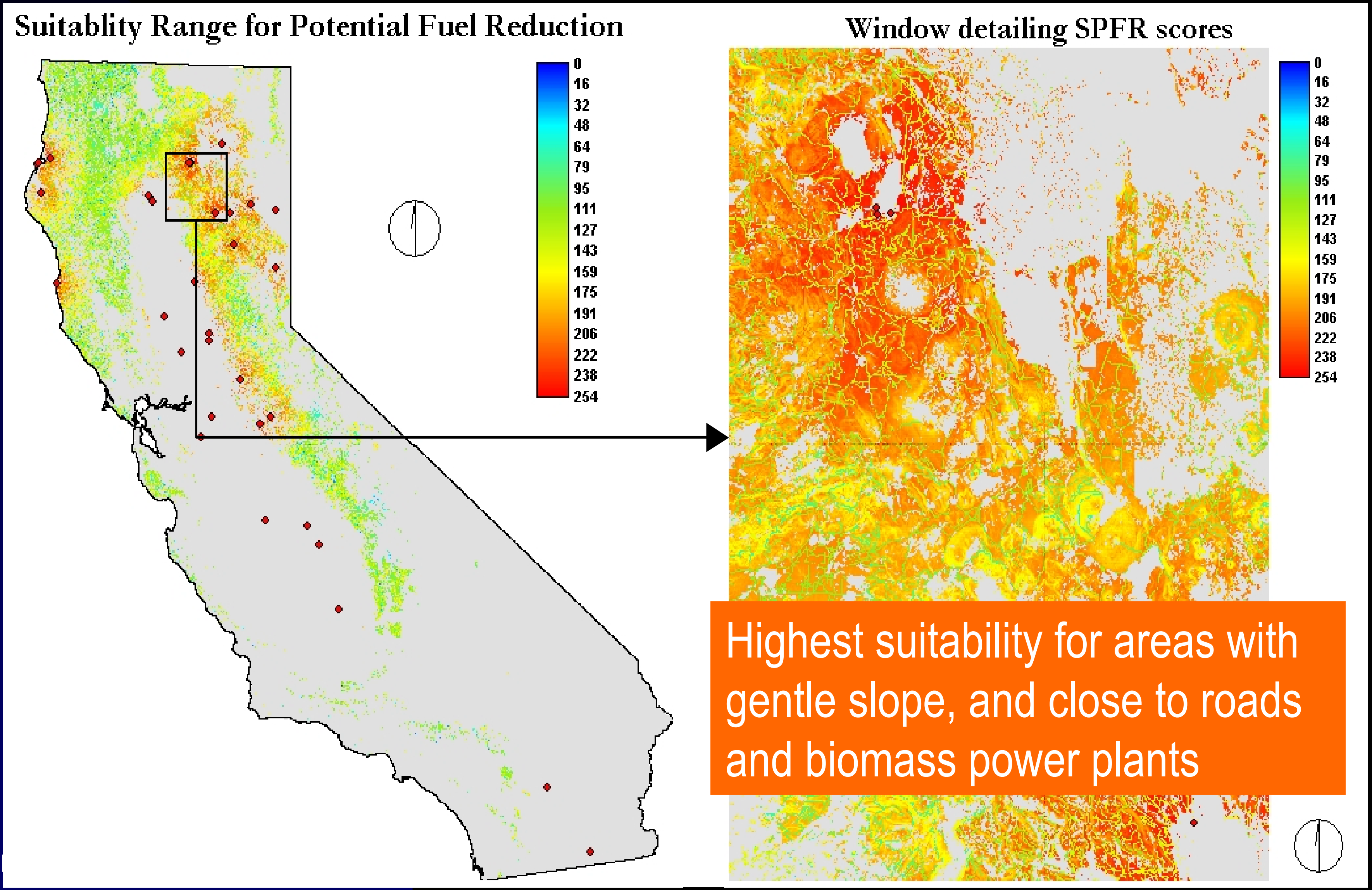






Wi

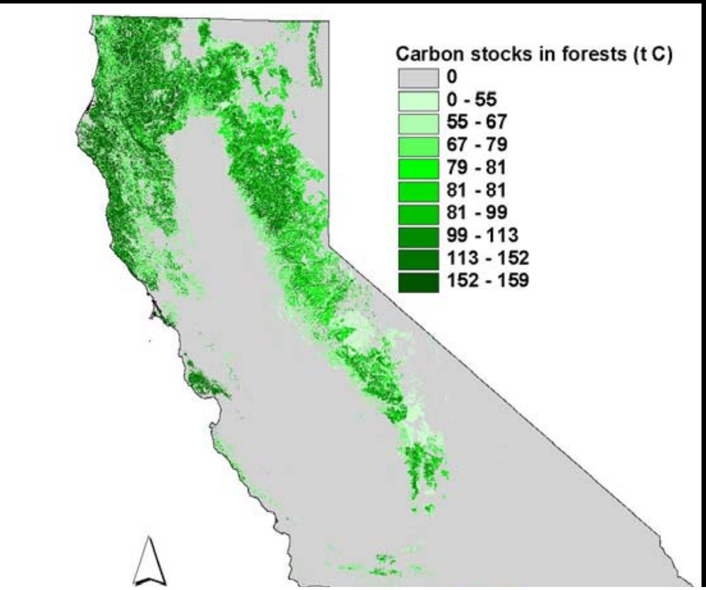
Map of suitability scores for potential fuel reduction for California forests

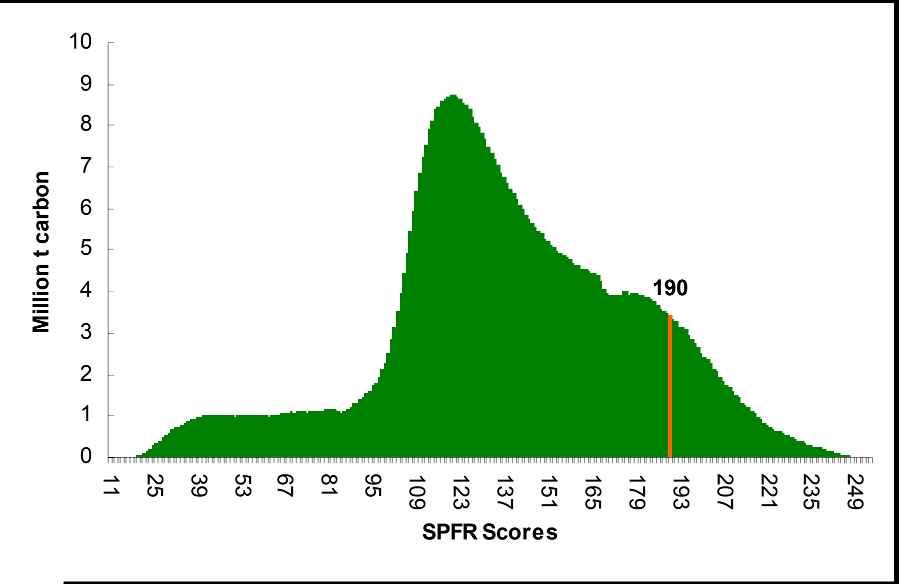


Highest suitability for areas with gentle slope, and close to roads and biomass power plants

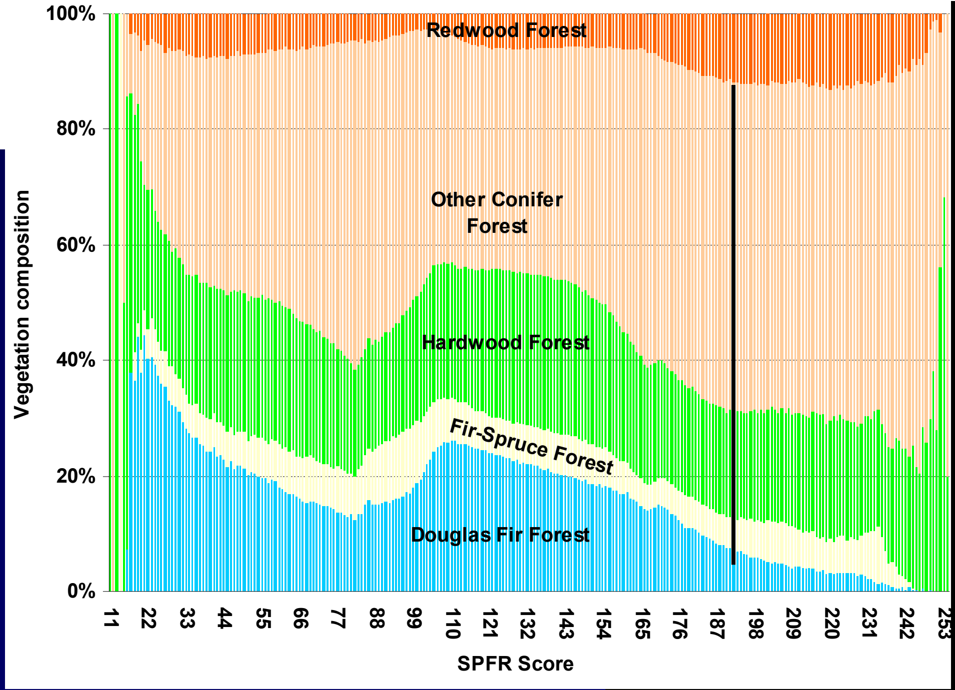
Wi

Carbon stocks in forests exposed to fire





Carbon stocks by SPFR classes for forests at high and very high risk for fire



Forest composition of the SPFR classes for areas at high and very high risk for fire.

Potential carbon emissions from fire

- Cumulative carbon stocks in forests at high and very high risk for fire with SPFR classes higher than the top 25% (score of 190) = 74.2 million t covering an area of approximately 775,000 hectares
- The estimated net emissions from these forests if they burned could be as much as 4.6 million t C (range for different forest classes =25-51 t C/ha)

Next steps

- The potential to reduce potential wildfire emissions plus substituting fossil fuels with biomass could be an important component of California's strategy to mitigate GHG emissions.
- Further work is warranted, including:
  - economic analysis of the gathering and transportation of the biomass fuels,
  - field data on effect of fires on carbon stocks,
  - the pattern of recovery of carbon stocks after fire,
  - fuel substitution costs and efficiencies at the power plant.

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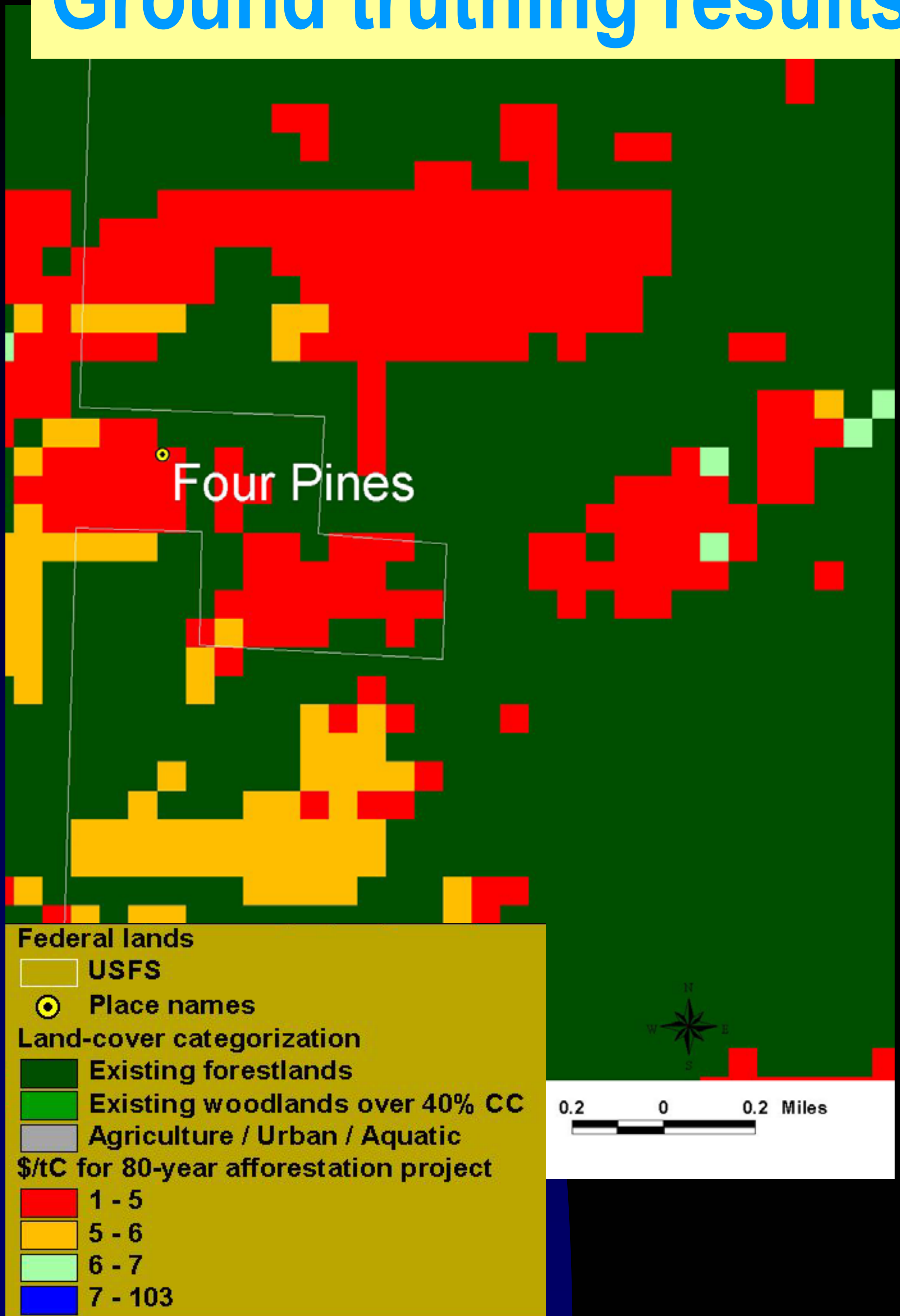
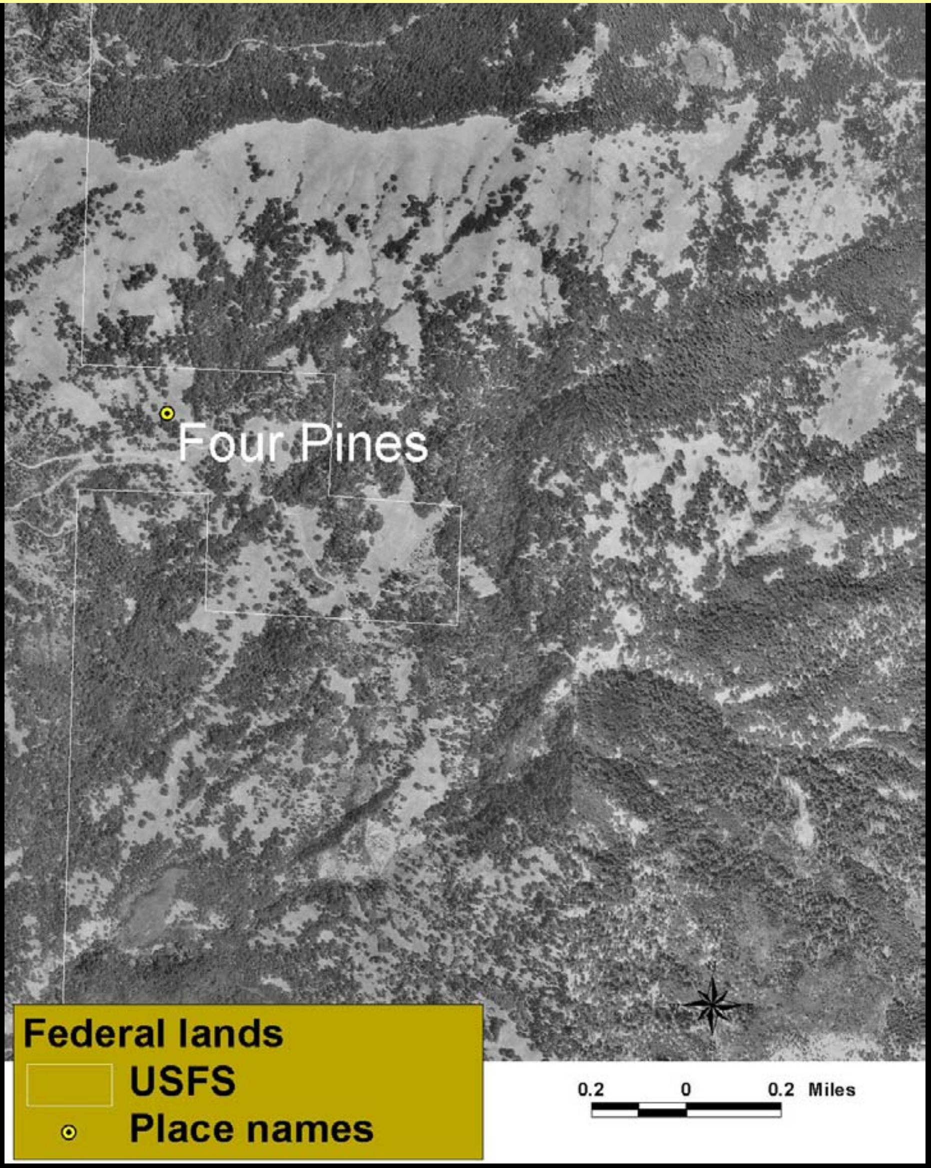
Ground truthing results—e.g. Mendocino County





1993 1m x 1m B/W aerial photographs